MINIMIZING DISTORTION IN STEGANOG-RAPHY BASED ON IMAGE FEATURE

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ABSTRACT

There are two defects in WOW. One is image feature is not considered when hiding information through minimal distortion path and it leads to high total distortion. Another is total distortion grows too rapidly with hidden capacity increasing and it leads to poor anti-detection when hidden capacity is large. To solve these two problems, a new algorithm named MDIS was proposed. MDIS is also based on the minimizing additive distortion framework of STC and has the same distortion function with WOW. The feature that there are a large number of pixels, having the same value with one of their eight neighbour pixels and the mechanism of secret sharing are used in MDIS, which can reduce the total distortion, improve the anti-detection and increase the value of PNSR. Experimental results showed that MDIS has better invisibility, smaller distortion and stronger anti-detection than WOW.

KEYWORDS

Information Hiding; Minimal Distortion; Secret Sharing; Eight Neighbour Pixels; PSNR; Anti-Detection

1. INTRODUCTION

With the rapid development of information technology, people enjoy the convenience of the information society but also suffer the threats of information disclosure and attacks. How to ensure the security of information has become the focus of information research fields [1]. In addition to the traditional information encryption technology, more and more scholars began to focus on the research of steganography. In recent years, image-based steganography has developed rapidly. In general it can be divided into two types of methods in which one is based on spatial domain and another based on frequency domain. The methods based on spatial domain have received much attention because of its large hidden capacity and simple implementation.

The more classic spatial information hiding algorithms are LSB (Least Significant Bit) and Patchwork [2] early. These two algorithms are simple to implement, but have small hidden capacity and poor anti-detection. In 2011, Gul et al. proposed an algorithm named HUGO(Highly Undetectable steGO), which has larger capacity and higher anti-detection compared to LSB and Patchwork. At the same year, Filler et al. proposed a complete practical methodology for minimizing additive distortion in steganography with general (non-binary) embedding operation using STC (Syndrome-Trellis Codes) [3]. Based on this framework, most of exist algorithms including HUGO can be implemented by designing different distorting functions. In 2012, in their later work, Holub and Fridrich proposed a new spatial algorithm named WOW which has also large capacity and high anti-detection based on the former framework.

Experimental results in [4] show that the overall performance of the WOW is superior to HUGO, LSB and Patchwork. After deep research, we found there are two defects in WOW. The total distortion grows rapidly with the increase of hidden capacity, and the anti-detection of the algorithm also decreases drastically. In this paper, we first introduce the basic idea and the defects of WOW, then proposed a new information hiding algorithm named MDIS. MDIS and WOW use the same distortion function. However, in the process of embedding the secret information using the minimal distortion path, the information hiding rule is redesigned based on the facts that many pixels always have the same value with one of its eight neighbour pixels. At the same time, the mechanism of secret sharing [5] is also used in MDIS. There are two advantages in MDIS compared to WOW. MDIS get smaller total distortion and higher anti-detection after using feature mining of over image. It is also ensured that the anti-detection does not decrease drastically when the hiding capacity increases after using the mechanism of secret sharing. Experimental results show that MDIS is superior to WOW in terms of PNSR, total distortion and anti-detection.

2. Basic Idea And Defects of WOw

2.1. Basic Idea Of WOW

In 2012, WOW was proposed by Holub and Fridrich based on the STC framework. For a given cover image(X) and secrete information (M), the stego image(Y) is got through the following steps:

(1) Calculating the hiding capacity according to the cover image and secrete information. If secrete information is m bits, the number of rows and columns is n_1 and n_2 in cover image, then the hiding capacity is as follows:

$$Payload = m / n_1 \times n_2 \tag{1}$$

(2) Calculating the minimal distortion path through distortion function according to STC framework. The distortion function is as follows:

$$D(X,Y) = \sum_{i=1}^{n_1}\sum_{j=1}^{n_2} \rho_{ij}(X, Y_{ij}) \left| X_{ij} - Y_{ij} \right| \tag{2}$$

In formula (2), $X_{i,j}$ and $Y_{i,j}$ respectively represent the value of pixel*(i,j)* in cover image and stego image. ρ_{ij} is the distortion parameter when X_{ij} becomes Y_{ij}. In WOW, WDFB-D Filter is used to calculate the value of ρ_{ij}. The specific calculation method is shown in formulas (3) and (4).

$$\varepsilon_{ij}^{k} = \left|R^{(k)}\right| * \left|R^{(k)} - R_{[i,j]}^{k}\right| \approx \left|R^{(k)}\right| * \left|K^{(k)}\right| \tag{3}$$

$$\rho_{ij}^{(p)} = \left(\sum_{k=1}^{F} \left|\varepsilon_{ij}^{(k)}\right|^{p}\right)^{-\frac{1}{p}} \tag{4}$$

In formula (3), for given filter $B_n = \{K^{(1)}, \ldots, K^{(F)}\}$, the value in the kth direction is $R^{(k)} = K^{(k)} * X$. If the value of pixel *(i,j)* changes, then the new value in the kth direction is $R_{[i,j]}^{k}$. In formula (4), the value of P is generally -1 and F represents the filtering direction.

(3) Information hiding is performed through change the value (plus or minus one) of pixels in minimal distortion path.

2.2. DEFECTS OF WOW

WOW is best in existing spatial algorithms. However, we found that there are two defects in WOW. One is that only the change of the value of pixels is considered in total distortion, but the feature of cover image is not utilized to server for hiding information. Another is that the total distortion grows obviously with the increase of hidden capacity, and the anti-detection of the algorithm also decreases drastically. Here we analyze these two defects in detail.

(1)Analyzing the feature of cover image

Spatial redundancy is ubiquitous in image data and it is usually caused by the spatial coherence between the colors of sampling points in a same scene surface. Especially the value of some pixel is always the same with one of its eight neighbor pixels. In experiment 1, we selected randomly 200 images with different sizes and types, and then respectively counted the number of pixels, having the same value with one of their eight neighbor pixels. The way of counting is shown in formula (5) and the results are seen in table 1.

$$\sum_{i=1}^{n1}\sum_{j=1}^{n2} if(X(i,j) == X(i',j'))\ Num = Num + 1 \qquad (5)$$

In formula (5), n_1 and n_2 is the number of rows and columns. $X(i',j')$ is one of the eight neighbor pixels which has the same value with pixel $X(i,j)$.

In order to compare and analyze intuitively, the results of multiple images are averaged. The specific statistical results are shown in Table 1:

Table 1. The number of pixels and percentage who have the same value with one of their eight neighbor pixels

Image type	Image size	Number	Percentage(*Number/n1*n2*)
landscape	600*800	226704	47.23%
people	680*1024	478094	68.66%
plants	780*1024	532946	66.73%
fruits	640*780	299970	60.09%

As can be seen from Table 1, there are nearly 50% pixels in the all randomly selected types of images that have the same values with one of their eight neighbor pixels. If we can utilize this feature to hide information, the change to cover image will be reduced. Then the total distortion also can be reduced and the anti-detection ability of the algorithm can be improved too.

To illustrate this feature of image can be applied to the algorithm, we designed the experiment 2. We selected randomly 50 images as cover images and use them to hide information with WOW. Then we counted the number of pixels whose value changed in minimal distortion path and among these pixels also counted the number of pixels who have the same values with one of their eight neighbor pixels. The statistical results are shown in Table 2.

Table 2. The number of pixels whose values changed in minimal distortion path

Hiding Capacity	$N_{changed}$	N_{same}	Percentage(N_{same}/ $N_{changed}$)
0.1	9040	1179	13.04%
0.2	20283	3074	15.16%
0.3	32970	5581	16.93%
0.4	46888	8666	18.48%
0.5	62107	12396	19.96%
0.6	78546	16829	21.43%
0.7	96299	22145	23.00%
0.8	114750	28375	24.73%

We can know that there are nearly 20% pixels whose values are same with one of their eight neighbor pixels in the minimal distortion path in WOW from table 2. And with the hidden capacity increasing, this image feature becomes more obvious. We can use this feature for information hiding algorithm. For each pixel in minimal distortion path has this feature, it represents a bit of hide information. In other word, without changing any value of pixels, embedding hiding information is done. Then the total distortion will be reduced and anti-detection will be increased.

(2)The total distortion growing rapidly with the increasing of hidden capacity

In wow, with the increasing of hiding capacity, the total distortion grows rapidly and caused a decrease in anti-detection property. We have done experiments to compare the total distortion with different hidden capacities and the results are shown in figure 1 and figure 2. Although the total distortion of WOW is smallest compared to other algorithms (seen from figure 1), the total distortion in WOW grows very fast with the increasing of hidden capacity (seen from figure 2). Especially when the hiding capacity is greater than 0.5, the value of total distortion almost becomes twice for hidden capacity increased by 0.1. We introduce the mechanism of secret information sharing in MDIS to solve this problem.

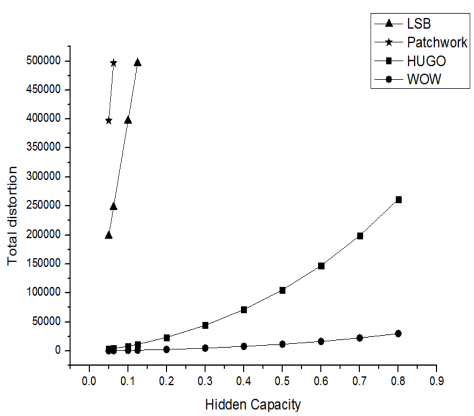

Figure 1. Total distortion of all algorithms

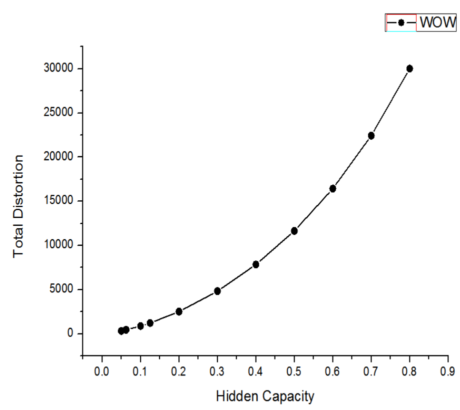

Figure 2. Total distortion of WOW

3. THE IDEA OF MDIS

We proposed a new algorithm named MDIS based on the above analysis of two defects in WOW. In MDIS, we use the same distortion function with WOW, but we redesign the hiding rule through the minimal distortion path. We combine the feature that there are lots of pixels whose values are same with one of their eight neighbor pixels and hiding information together. In addition we also join the mechanism of secret information sharing in MDIS. The basic idea of MDIS is as follows:

(1) Combining Hiding Information and the Feature of Image Together

In MDIS, the minimal distortion path is found according to distortion function and hiding capacity. For each pixel in the minimal distortion path, we first check if there exists one of eight neighbor pixels whose value is same with this pixel. If the condition is true, it means there is a bit (0 or 1) of hidden information and we need not do anything to hide information. If it is false, then we select its adjacent pixel having the smallest distance and not in the main direction [6] of the image to do the operation (plus 1 or minus 1) to hide information.

We do this for the following reasons. First we avoid changing in the main direction to reduce the impact of modification in cover image. Second, we choose to modify the adjacent pixels is to not follow the traditional thinking in order to improve the security and reduce the probability of being detected. Experimental results show that this hiding strategy provides MDIS better anti-detection than WOW.

In the minimal distortion path, the algorithm for locating the position of the pixel where the secret information is embedded is as follows:

```
For each pixel P(x,y)  in the minimal distortion path

  iSame = 0;     //by default, no neighbor pixels whose value is same with this pixel
  iDiff = 255;   //by default, the distance is 255
  changePos = (x,y);  //By default, the pixel where the secret information is embedded
  Foreach  P(x1,y1)  in  sets of eight neighbor pixels
    If (x1,y1) is not valid   continue;
    If P(x1,y1)== P(x,y)    iSame=1  ; break;
    iTempDiff = abs(P(x,y), P(x1,y1);  //get the distance of these two pixels
    if (iTempDiff < iDiff) && isNotMainDirection(x,y,x1,y1)
        iDiff = iTempDiff;
        changePos = (x1,y1);            //the inner loop ends here
    if (0 ==iSame)
       p(changePos) = p(changePos) + 1;
    or p(changePos) = p(changePos) - 1  ;   //hiding information
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(2) With the mechanism of secret information sharing

In MDIS, there is a parameter named *MaxPayload*. When the hidden capacity exceeds *MaxPayload*, the secret information is divided into multiple parts using modulo operation. Each part will be hidden in a same cover image. Of course, the hiding capacity in each cover image is not exceeds *MaxPayload*. The design of dividing information includes three steps. Step one is getting the value of *N* (round up) and N is equal to *hidden capacity/MaxPayload*. Step two is choosing a random number *M* (*M*>=*N*) between 1to 9. Step three is using *M*, *N* and *P* (the location of every bit of hide information) to divided hidden information into *N* parts according to the value of *P%M*. Details are shown in figure 3:

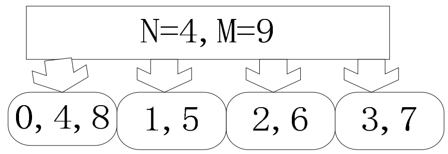

Figure 3. N=4，M=9；the first part information($P\%M$ =0,4,8)，the second part information($P\%M$ =1,5) ，the third part information($P\%M$ =2,6)，the forth part information($P\%M$ =3,7)

After using secret sharing, there will be multiple stego images. So receiver must get complete hidden information through the inverse of modulo operation from these stego images.

4. EXPERIMENTAL RESULTS AND ANALYSIS

In order to compare the performance of two hidden algorithms, MDIS and WOW, we focus on the PNSR, total distortion and anti-detection in different hidden capacity.

4.1. COMPARING AND ANALYZING THE PNSR IN DIFFERENT HIDDEN CAPACITY

The hidden capacity of MDIS, WOW and HUTO is 0-0.8, but the hiding capacity of LSB is 0-0.125. Here we choose PSNR to compare and analyze. PSNR is an important technical indicator which can be used to determine whether the visual effect is good. PSNR also is an effective parameter standard to judge the invisibility of the algorithm. The larger the value of PSNR, the better the hiding effect is. We choose four standard images as cover images to do the test, four standard test images are shown in figure 4.

（a）Lena (b) Barbara (c) Cameraman (d) baboon

Figure 4. Test images

We calculate the value of PSNR in different hidden capacity. The experimental results are shown in table 3 and figure 6. From the results used Lena as cover image in table 3, we know that the value of PSNR in MDIS is highest in the same hiding capacity and followed by WOW, HUGO and LSB.

Table 3. The value of PSNR in different hidden capacity using Lena as cover image

Hiding Capacity	PSNR（MDIS）	PSNR(WOW)	PSNR(HUGO)	PSNR(LSB)
0.05	73.2421	72.5481	71.7548	55.1286
0.125	68.9979	67.9929	67.3914	51.1288
0.4	63.4265	62.0965	61.6407	——
0.8	60.1731	58.463	58.1732	——

There is a graphical representation of average PSNR of four standard images in different hidden capacity and different hiding algorithms in figure 5. We know that the trend of PSNR is consistent using all algorithms. The larger the hidden capacity, the smaller the value of PSNR is. But under the same cover image and the same hidden capacity, the performance of MDIS is best. That means the invisibility of MDIS is best.

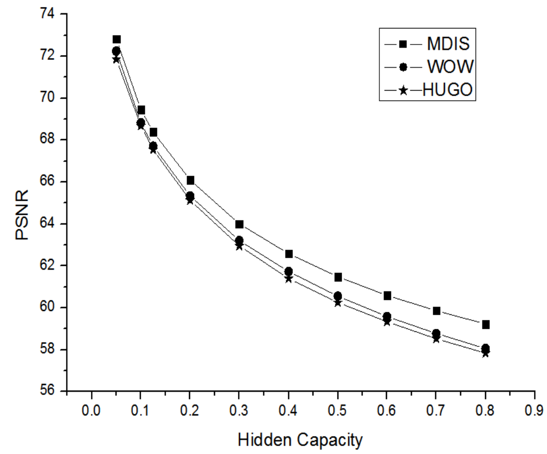

Figure 5. The analysis of PSNR in MDIS, WOW and HUGO

4.2. The Analysis Of Total Distortion In Stego Image

Because there is a same distortion function in WOW and MDIS, so it is very meaningful to compare the total distortion in the same hidden capacity. In the same hidden capacity, the one which has larger distortion has worse anti-detection. Using the tool of MATLAB and choosing randomly 50 images, we design two experiments. The first experiment is comparing and analyzing the total distortion without secret sharing. The second experiment is comparing and analyzing the total distortion with secret sharing. In the second experiment, there are multiply stego images, so we get the average total distortion. For MDIS, if it is not using secret sharing, we named it as MDIS-NS, else named it as MDIS. And we set *MaxPayLoad* = 0.3. The experimental results are shown in figure 6.

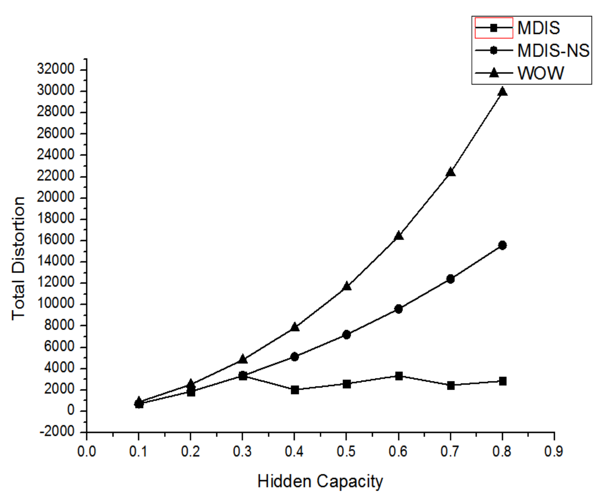

Figure 6. The total distortion of WOW, MDIS-NS and MDIS

From figure 6, although there is a same distortion function, even not using secret sharing, the total distortion in MDIS is smaller than in WOW in a same hidden capacity. As the hidden capacity increases, the gap between the two algorithms becomes more and more obvious. When the hidden capacity is greater than 0.5, the total distortion in WOW is almost twice as in MDIS. That means our operation for hiding information play a great role and the effect is very obvious. After using secret sharing, the average total distortion in multiply stego images in MDIS is much smaller than in WOW, and the effect is very prominent. Obviously, MDIS has much better performance in total distortion than WOW.

4.3. Comparing And Analyzing Anti-Detection

In our experiments, we choose two features: SPAM and SRM to analyze the anti-detection of algorithms [7, 8]. We design two experiments to test the anti-detection in different hidden capacity of three algorithms (MDIS-NS, MIDS and WOW). We set *MaxPayload* = 0.3 and use EOOB [9] as the measurement of anti-detection. The higher the value of EOOB, the higher the probability of detection error, the better anti-detection performance of the algorithm has.

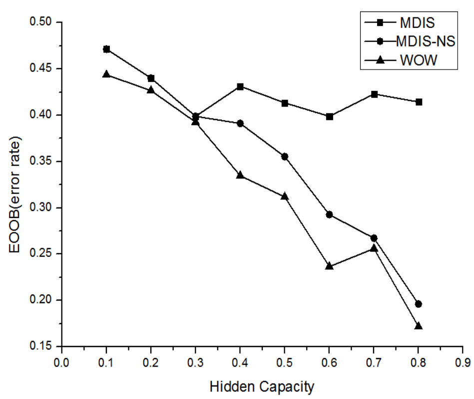

Figure 7. The anti-detection based on SPAM

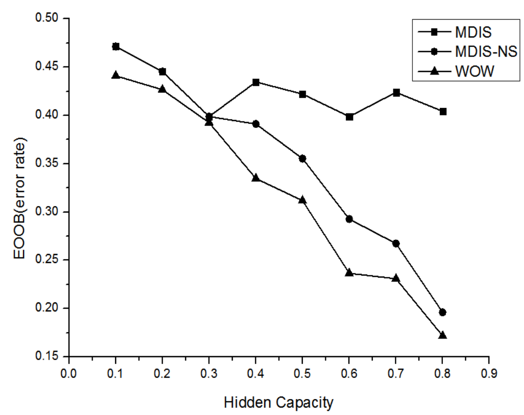

Figure 8. The anti-detection based on SRM

From figure 7 and figure 8, we can find that the trend of EOOB is very similar based on SPAM and SRM. With the increasing of hidden capacity, the EOOB in MDIS-NS and WOW has been falling too. But there is higher EOOB in MDIS-NS. Another point, the EOOB in MDIS is basically kept parallel after the hidden capacity exceeds 0.3. That means the anti-detection does not decrease with the increase of the hidden capacity. This is a very big improvement compared to WOW. So, we can conclude that the performance of MDIS-NS and MDIS are better than WOW.

5. Conclusions

We proposed a new information hiding algorithm name MDIS, combining minimal distortion and image feature together, based on two defects of WOW. At the same time, we joint a secret information sharing mechanism in MDIS. The experimental results show that MDIS has better performance than WOW. MDIS has higher PSNR, smaller total distortion and higher EOOB than WOW. That means MDIS has better invisibility, smaller distortion and stronger anti-detection than WOW. There is still room for improvement in MDIS. The cover images must be used when the secret information is restored.

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REFERENCES

[1] Slaughter & Jason & Rahman & Syed Shawon M, (2011) "Information Security Plan for Flight Simulator Applications", International Journal of Computer Science and Information Technology, Vol. 3, No. 3, pp1-15.

[2] Bender W & Gruhi D & Morimoto N, (1996) "Techniques for Data Hiding", IBM System Journal, Vol. 35, No. 3, pp313-335.

[3] T. Filler & J. Judas & J. Fridrich. (2011) "Minimizing additive distortion in steganography using syndrome-trellis codes". IEEE TIFS, Vol. 6, No. 3, pp920-935.

[4] Li-qiong Lu & WuDong, (2015) "Research of the Digital Image Steganography based on spatial domain", Joural of lingnan normal university, Vol. 1, No. 3, pp105-111.

[5] ChenGouxi & ShenHonglei & Wuyuliang & ChenJunjie, (2012) "Research on Sharing and Steganographic Algorithm for Batch Cover Image", Computer Engineering, Vol. 1, No. 4, pp116-118.

[6] B.M. Mehtre, (1993) "Fingerprint image analysis for automatic identification", Machine Vision and Application, Vol. 1, No. 6, pp124-139.

[7] T.Pevny & P.Bas & J.Fridrich, (2010) "Steganalysis by Subtractive Pixel Adjacency Matrix", IEEE Trans. on Info. Forensics and Security, Vol. 5, No. 2, pp215-224.

[8] C.Chen & Y.Q.Shi, (2008) "JPEG image steganalysis utilizing both intrablock and interblock correlations", International Symposium on Circuits and Systems, Vol. 7, No. 1, pp3029-3032.

[9] Jan Kodovský & Jessica Fridrich, (2010) "Ensemble Classifiers for Steganalysis of Digital Media", Forensics and Security, Vol. 7, No. 2, pp432-444.

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